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# OBSERVATIONS ON THREE VARIETIES OF HOPI MAIZE[1]

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RECENT STUDIES by Mangelsdorf and Smith (1949) on prehistoric plant remains recovered during archaeological excavations at Bat Cave, New Mexico, establish the antiquity of maize in southwestern United States. Furthermore, it is clear that maize is closely associated with the history of peoples of this area (Carter, 1945; Carter and Anderson, 1945), and may, therefore, provide critical material for ethnological as well as botanical investigations. For these reasons alone a clearer understanding of the major varieties of southwestern maize is to be desired. There are, in addition, other reasons for a more complete survey and subsequent preservation of southwestern varieties. For investigations in pure genetics this material provides a stockpile of genes that has never been adequately sampled or studied, and unless these various strains are soon rescued, it is inevitable that many of them will be lost to science. Finally, germ plasm of agricultural value may reside in certain of the southwestern Indian corns. The fact that this material has not in the past or is not now being utilized in corn improvement programs cannot be taken as a reliable criterion of its usefulness. Our present knowledge of what is needed in the improvement of modern corns is not sufficient to permit one to predict with any accuracy what kinds of corns will be useful in breeding 50 or 100 years hence.

Unfortunately, for the student of maize, the impact of modern civilization has had its effect, not only on the daily habits and economy of the southwestern Indian, but on his crop plants as well. Thus many of the corn varieties of a century ago are now extinct and others show the effects of much intervarietal hybridization. Some of the southwestern tribes are still growing varieties of maize which differ but little from those grown by their ancestors some centuries ago. It seems desirable to record, while it is still possible to do so, the variation pattern of the more important and critical of these varieties.

Among southwestern Indians, the Hopi are perhaps the most conservative. Predominately agricultural throughout their long history in an arid country, they have established a reputation as superior dry-land farmers. Their conservatism, which has long been recognized by ethnologists, is reflected in their crop plants, particularly their maize.

Hopi maize has previously received considerable attention, both from botanists and ethnologists. The ethnobotanical studies of Whiting (1939), based on collections of Whiting and Jones, provide varietal names, descriptions and uses of most Hopi varieties. A part of this collection is now preserved in the Museum of Northern Arizona where we have had opportunity to examine it in detail. Carter and Anderson (1945) included nineteen ears of Hopi corn in their survey of southwestern maize, and although they do not refer to specific varieties, their statement that "some of it is almost identical with Basketmaker maize" indicates that the variety Kokoma was included in their material. The present account should be considered a supplement to these previous studies since we have made no attempt to investigate intensively all modern Hopi corns. Instead, we shall describe the overall variation pattern among three of the more important varieties that are currently available and relate this pattern to what is known of the evolutionary history of southwestern maize in general.

For the Hopi people, corn is of paramount importance. It has been their most important food item, truly their staff of life. The growing of corn, the care of the harvested crop and the preparation of corn for food have been the principal occupation of the Hopi men and women for centuries. And their folklore, traditions and religious rituals have in large part been woven around corn as a central theme. To each child, in early infancy, is dedicated an ear of corn, his or her "corn-mother." From that time on, corn is in some way interwoven with

[1] Received for publication April 11, 1952.

The authors wish to express their appreciation to Dr. Harold S. Colton, Director, Museum of Northern Arizona, for facilities kindly provided by the Museum, and to Dr. Katharine Bartlett of that institution for many helpful suggestions. A grant from Pioneer Hi-Bred Corn Company to help defray costs of illustrations is gratefully acknowledged.

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TABLE 1. *Ear measurements of Hopi maize.*

| Specimen No. | Shank diam. (mm.) | Width mid-ear (mm.) | Rows | Denting | Kernel width (mm.) | Kernel thickness 10 kernels (mm.) | Aleurone color | Multiplication[a] |
|---|---|---|---|---|---|---|---|---|
| | | | | *Blue Flour* | | | | |
| 1 | 18 | 33 | 12 | 0 | 7 | 40 | Purple | Many |
| 2 | 25 | 35 | 14 | 1 | 6 | 42 | Purple | 0 |
| 3 | 18 | 35 | 12 | 1 | 7 | 41 | Purple | 2 |
| 4 | 17 | 35 | 12 | 0 | 7 | 42 | Purple | Slight |
| 5 | 9 | 33 | 12 | 0 | 6 | 42 | Purple | 0 |
| 6 | 16 | 36 | 14 | 0 | 7 | 47 | Purple | 2 |
| 7 | 19 | 36 | 20 | 0 | 4 | 47 | Purple Few White | Several |
| 8 | 18 | 36 | 12 | 0 | 7 | 44 | Purple | 0 |
| 9 | 12 | 27 | 16 | 0 | 6 | 46 | Purple | Slight |
| 10 | 19 | 36 | 12 | 0 | 7 | 39 | Purple | Slight |
| 11 | 20 | 35 | 14 | 0 | 6 | 40 | Purple | 0 |
| 12 | 9 | 37 | 14 | 0 | 6 | 45 | Purple | 0 |
| 13 | 16 | 40 | 16 | 0 | 7 | 42 | Purple | Slight |
| 14 | 23 | 39 | 16 | 0 | 6 | 47 | Purple | 0 |
| 15 | 17 | 38 | 14 | 1 | 7 | 51 | Purple | 0 |
| 16 | 20 | 36 | 12 | 0 | 7 | 42 | Purple | Slight |
| 17 | 14 | 35 | 12 | 0 | 6 | 40 | Purple | Slight |
| 18 | 20 | 38 | 12 | 0 | 7 | 47 | Purple | Slight |
| 19 | 14 | 35 | 12 | 0 | 7 | 44 | Purple | Slight |
| 20 | 21 | 41 | 16 | 0 | 6 | 37 | Purple | Several |
| 21 | 23 | 38 | 14 | 0 | 7 | 43 | Purple | Several |
| 22 | 20 | 36 | 10 | 0 | 8 | 42 | Purple | Slight |
| 23 | 22 | 37 | 12 | 1 | 7 | 40 | Purple | Slight |
| 24 | 14 | 38 | 14 | 0 | 7 | 44 | Purple | 0 |
| Av. | 17.7 | 36.0 | 13.5 | | 6.6 | 43.1 | | |
| | | | | *White Flour* | | | | |
| 1 | 12 | 37 | 12 | 0 | 8 | 41 | Colorless | 0 |
| 2 | 14 | 43 | 12 | 0 | 8 | 41 | Colorless | Slight |
| 3 | 21 | 39 | 14 | 0 | 8 | 49 | Colorless | 0 |
| 4 | 27 | 49 | 16 | 0 | 8 | 43 | Colorless | Slight |
| 5 | 21 | 43 | 14 | 0 | 9 | 55 | Colorless | Slight |
| 6 | 17 | 41 | 12 | 1 | 10 | 44 | Colorless | Several |
| 7 | 29 | 46 | 14 | 1 | 9 | 46 | Colorless | Several |
| 8 | 26 | 45 | 16 | 0 | 9 | 45 | Colorless | Few |
| 9 | 25 | 42 | 12 | 1 | 9 | 48 | Colorless | Few |
| 10 | 20 | 44 | 14 | 1 | 9 | 50 | Colorless | Slight |
| 11 | 27 | 40 | 12 | 0 | 9 | 43 | Colorless | Slight |
| 12 | 19 | 42 | 14 | 0 | 8 | 47 | Colorless | Slight |
| 13 | 17 | 40 | 16 | 0 | 7 | 50 | Colorless | Slight |
| 14 | 22 | 38 | 12 | 0 | 8 | 45 | Colorless | Several |
| 15 | 16 | 40 | 12 | 0 | 8 | 40 | Colorless | 0 |
| 16 | 23 | 36 | 10 | 0 | 9 | 41 | Colorless | Many |
| 17 | 23 | 40 | 12 | 0 | 9 | 40 | Colorless | Slight |
| Av. | 21.1 | 41.5 | 13.2 | | 8.5 | 45.2 | | |
| | | | | *Kokoma* | | | | |
| 1 | 9 | 31 | 12 | 0 | 6 | 50 | Purple | 0 |
| 2 | 12 | 38 | 12 | 0 | 7 | 40 | Purple | Slight |
| 3 | 9 | 32 | 12 | 0 | 6 | 36 | Purple | Slight |
| 4 | 10 | 31 | 14 | 0 | 6 | 44 | Purple | 0 |
| 5 | 16 | 34 | 12 | 0 | 7 | 38 | Purple | Slight |
| Av. | 11.2 | 33.2 | 12.4 | | 6.4 | 41.6 | | |

[a] As defined by Cutler (1946) and measured in terms of extra kernels on the ear.

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nearly all phases of life. Hopi agriculture and economics are primarily based on corn; and their civilization (culture) has been built up around life largely preoccupied with corn. Thus it is that extreme care and patience is lavished on every operation involving corn. This holds especially for the selection of seed to be planted, and for the assignment of land for the different varieties, two items which tend to perpetuate their ancestral types.

Only in the most conservative of the Hopi villages may one hope to find the ancestral types without substantial admixture from outside sources. For this reason, most of our material was collected from Hotevilla, the most conservative village. In general there was less evidence of intervarietal mixing at Hotevilla than at any of the other seven villages we visited.

The collections were made in the latter part of September, 1950, a dry year in which the corn crop was below average. Tassels[2] (male inflorescences) were collected from fields in the vicinity of Hotevilla. An effort was made to take the specimens at random from fields of relatively pure varieties. At this time, the plants were not sufficiently mature to provide good ear specimens. Our ear measurements were made on stored corn harvested the previous year. Since ears were not taken directly from the fields, opportunities for obtaining random samples were not as good as in the case of tassels. Ear measurements on Blue Flour were from Hotevilla, on White Flour from Hotevilla and Old Oraibi, on Kokoma from Shungopovi. No measurements were made on the corn examined at Walpi, Shipaulovi, Mishongnovi and Moenkopi.

Culture.—Hopi corn fields are located in three kinds of places: on the flats below the mesas where shallow sand dunes form a mulch that retains the moisture in the soil below; close to the foot of the mesas, where flood waters pouring off the cliffs can be spread over the field; and the small patches on the mesa tops or on the ledges where either dunes or flood waters provide the moisture. The agricultural settlement at Moenkopi in the Navajo Reservation utilizes the alluvial bench of Moenkopi wash for both irrigated and unirrigated plantings. At Hotevilla a very limited amount of corn is planted in the terraced gardens below the village spring. Since water, or the lack of it, has always been a problem with the Hopi, the corn fields are located where there is greatest likelihood of soil moisture regardless of the distance removed from the village, and it is not uncommon for a Hopi farmer to till fields which are removed by as much as 10 mi. from the village in which he lives. Practically all of the field work is done by hand with the exception of "weed clearing" prior to planting. This chore is sometimes reduced by the aid of a crude weed cutter drawn by a horse. Fields are not plowed. After the weeds are removed, the sand is scraped away from an area a foot or so in diameter and a hole for receiving the kernels is dug with a modern iron planting stick. Eight to twelve kernels are placed in each opening and are then covered carefully by hand, using first the moist soil and then sand. The hole may be 3 or 4 in. deep in the soil, but 12 or even 18 in. below the surface of the sand. The hills are spaced three steps apart in the row and rows are likewise three steps apart, and if a near perfect stand results, the plants are thinned to five or six per hill. To a midwestern agriculturist the wide spacing of hills and rows as practiced by the Hopi is indeed a surprise—yet they have learned from experience that the kinds of corn they grow respond very poorly to closer spacing. Cultivation is accomplished almost entirely by hoe, usually of Spanish design, and the fields are frequently kept completely free of weeds. Fields may vary in size from small areas containing no more than fifteen hills of corn to others which may total almost 10 acres, the size depending almost entirely upon the amount of moisture available at any one location. In contrast to many of the southwestern tribes the Hopi seldom intermix plantings of corn and other crop plants within a single field. While melons are frequently grown in the same fields with corn, they are usually planted separately at one side of the field and not as mixed plantings with the corn. Although some of the ears may be used as green corn, harvesting of the major portion of the crop is done after the corn is well-matured. Corn ears are usually broken from the stalks and brought in to the village where the husks are carefully removed and the ears dried in the sun and open air. The better husks are tied in bundles to be used as wrappings for cooking tamales and other corn meal preparations. Corn stalks are bundled up and later used as feed for livestock. The ears are carefully sorted and when dry are stored in the owner's house or in other buildings. They are commonly stacked like cordwood against the wall, each variety separately.

Among the Hopi it is an established custom to keep the harvest from one season's crop in storage until the next year's crop is matured. For example, the corn used for food in any one year is that resulting from the crop of the previous rather than the current growing season. Thus the Hopi operate a sort of crop insurance system that assures them of a food supply even in years of crop failure.

Varieties.—Our data are concerned only with three major varieties, namely, (1) White Flour, (2) Blue Flour and (3) Kokoma or Purple corn. These are admittedly but a small segment of the many strains and substrains of Hopi maize that have been described, but they do represent three distinct races embodying the two most commonly grown varieties plus what appears to be one of the more primitive strains of southwestern maize.

[2] Tassels on which these studies are based are now included in the maize collection of the Missouri Botanical Garden.

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*White Flour.*—This is one of the most commonly grown varieties among the present day Hopi. It is found among fields of practically all Hopi farmers and it provides one of the main sources of meal or flour. White Flour is usually planted during the latter part of May and the resulting crop is harvested near the middle of October. The plants at maturity reach a height of approximately 3½ or 4 ft. (fig. 5). They tend to be light green in color and the plants are almost devoid of anthocyanin color in the leaves, sheaths and tassels. There is a rather strong tendency for tillering, but the expression of tillers is ordinarily inhibited by the thick planting within hills. Internode lengths of the main culm are much reduced above the ear, resulting in an internode pattern (fig. 1) approaching that of Mexican dents. When compared with the rather low plant height, the many branched, wide spreading tassels of White Flour give the impression of being vastly oversized and out of proportion. Although the number of secondary branches is variable, it averages ten or more. One of the most conspicuous features of the tassel is the extreme length of the central spike which is particularly striking in the field. Among varieties known to the writers, such extremely long central spikes have only been found in some varieties from western Mexico.

In addition to color differences, the ears of White Flour are readily distinguished from other Hopi varieties by several morphological features of which the most conspicuous are the wide diameter of the shank, the absence of basal compression of the ear (shown graphically in fig. 3) and the width of the kernels. Despite the presence of 14 or more rows of kernels, the kernels are very wide compared with those of other Hopi varieties (fig. 2). This is believed to be an expression of eastern influence and will be discussed in more detail later. Kernels of White Flour tend toward the crescent shape of eastern eight-row varieties although this tendency is modified somewhat in those ears which have a high number of rows of kernels. Kernels are characterized by white endosperm and colorless pericarp and aleurone. Occasionally one finds ears whose grains are flushed with pink or light cherry pericarp color.

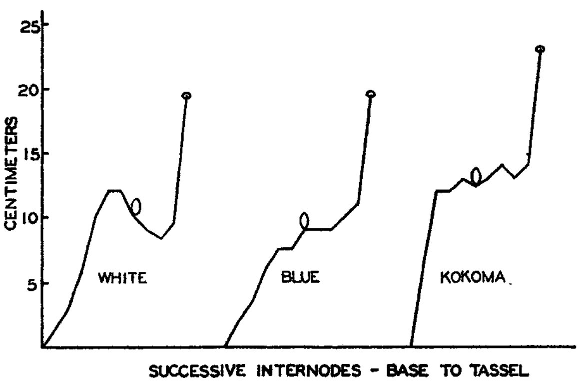


Fig. 1. Internode diagrams of three varieties of Hopi maize.

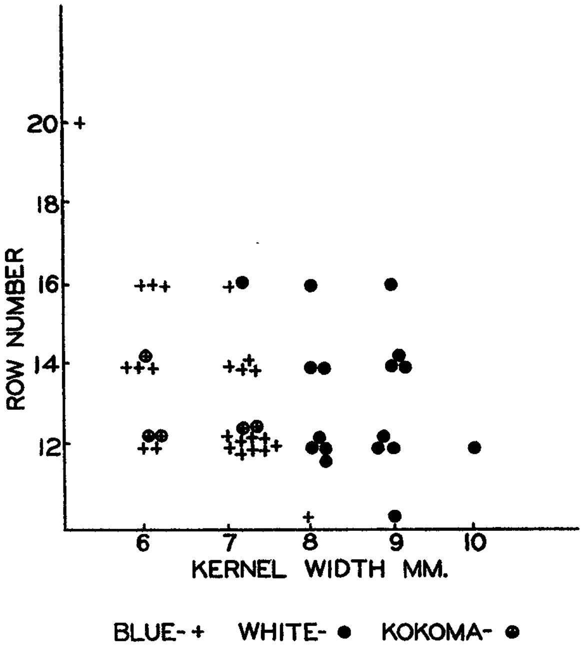


Fig. 2. Scatter diagrams depicting relationship between kernel width and row number in three varieties of Hopi maize. Each symbol on the diagram represents measurements of one ear.

*Blue Flour.*—This variety probably exceeds in importance as a source of food the extensively grown White Flour described above. It is approximately the same maturity as White Flour, being planted the latter part of May and harvested near the middle of October. Plant height at maturity is approximately 4 ft., and although the general plant appearance is similar to that of the white variety, there are certain differences in culm, tassel and leaves that distinguish the two varieties. The internode pattern of Blue Flour differs from that of the White in having fewer condensed internodes above the ear (fig. 1), resulting in a plant of more open and less leafy appearance. Tassel branch number is roughly the same as that found in White Flour and this variety is likewise characterized by long central spikes. Condensation of spikelet pairs in the secondary tassel branches in Blue Flour is somewhat less than that of the White variety, the average condensation index being 1.08 compared with 1.10 for White Flour. Culm width at the base of the tassel and internode length of the central spike are both less in Blue than in the White variety. This is shown graphically in fig. 4 and again suggests that Blue Flour contains less eastern and Mexican germ plasm than does the White corn. The leaves of Blue Flour are extremely long in relation to the height of the plant (fig. 6); in fact, some of the leaves are as

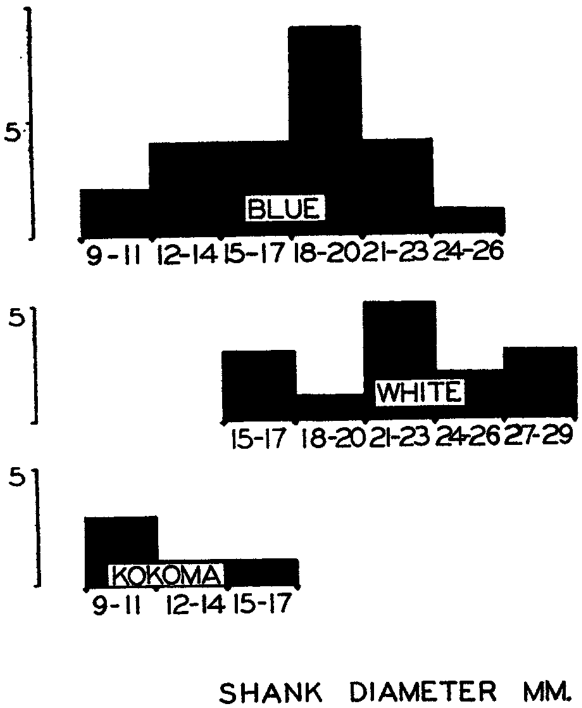


Fig. 3. Frequency distribution of shank diameters in Hopi Blue, Hopi White and Kokoma maize.

long as the plant is high. Row numbers in Blue Flour range from 10–20 with a mean of 13.5. Kernels are relatively narrow and shank diameter is considerably less than that of White Flour. Many ears of the variety exhibit a distinct basal compression that is almost completely lacking in the White corn. Kernel color consists of white endosperm, blue aleurone and colorless pericarp. Intensity of blue color is variable, with occasional ears showing a light or grayish blue color. Although these have been described as a distinct variety by Whiting (1939), we have been unable to find any way in which they differ from the darker strains other than in intensity of color, and for that reason we do not consider them to represent separate entities.

*Kokoma, Purple Dye Corn.*—For several reasons, our data on Kokoma corn are based on a relatively small number of tassel and ear measurements. In the first place, the variety is not grown extensively and is, therefore, not as easy to come by as other more commonly used strains. Secondly, much of the so-called Kokoma corn we observed was thoroughly intermixed with other varieties and resembled the pure strains in seed color only. The most authentic ear specimens were found at Shungopovi, and it is from this collection that the ears shown in fig. 7 were photographed while our Kokoma tassel data are from specimens grown near Hotevilla. Conditions under which the plants were grown were not nearly as favorable as they were in the case of the Blue and White Flour varieties. Largely as a result of inadequate moisture these plants had not attained normal growth, and this fact should be kept in mind when studying the Kokoma data. One conspicuous feature of Kokoma corn is plant color. In contrast to the usual green color of Blue and White Flour, the leaf sheaths and tassels of Kokoma are conspicuously colored. The condensation index is roughly the same as that of Blue and White Flour, but the lengths of the staminate glumes are considerably reduced. Among the plants we examined at Hotevilla there was only a small degree of tillering, but this was probably due to the adverse conditions under which the plants were growing since the small culture of Kokoma plants grown in Iowa in 1951 produced as many tillers as did the other varieties. The ears of Kokoma are more "Basket Maker"-like than any of the other Hopi varieties examined. They are roughly cigar shaped with the widest diameter at a subbasal position from which point the ears taper gently toward the tip and somewhat more abruptly toward the base. Shank attachments are narrow and there is a complete absence of basal swelling that characterizes Hopi White and certain other southwestern varieties. The basal one-quarter of the ear usually exhibits distinct longitudinal striations on the seeds indicating the presence of tight husks. Row numbers are either 12 or 14 and the kernels tend to be isodiametrical in cross-section. Kernel color is due to an intense cherry pericarp, so deep as sometimes to appear black. It is the result of an interaction of the cherry allele of the *R* series with dominant *Pl* for plant color. The intense purple husks of Kokoma are sometimes used as a source of dye.

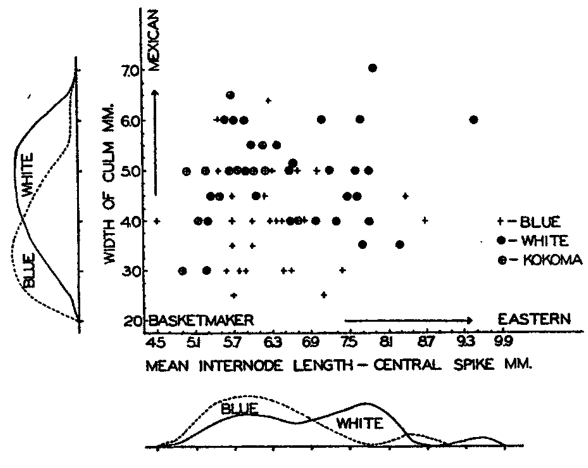


Fig. 4. Scatter diagram showing relationship between mean internode length of central spike and width of the culm (measured at the base of the tassel) for three varieties of Hopi maize. Each symbol on the diagram represents the position of a single tassel. The distribution of class frequencies for both White and Blue Flour are shown outside the diagram.

TABLE 2. *Tassel measurements of Hopi maize.*

| Specimen No. | Condensation | Width of culm (mm.) | Mean internode length (central spike) (mm.) | Glume length (mm.) | Length central spike (cm.) | No. sec. branches | Pedicel length (mm.) |
|---|---|---|---|---|---|---|---|
| | | | *Blue Flour* | | | | |
| 1 | 1.0 | 4.0 | 6.2 | 10 | 32 | 14 | 3.35 |
| 2 | 1.0 | 4.0 | 6.0 | 10 | 36 | 7 | 5.50 |
| 3 | 1.0 | 3.5 | 6.0 | 9 | 34 | 15 | 4.90 |
| 4 | 1.2 | 2.5 | 7.1 | 10 | 43 | 8 | 7.50 |
| 5 | 1.0 | 3.0 | 5.9 | 9 | 22 | 7 | 1.05 |
| 6 | 1.2 | 5.0 | 7.0 | 11 | 37 | 7 | 1.00 |
| 7 | 1.0 | 3.0 | 5.6 | 9 | 24 | 5 | 2.80 |
| 8 | 1.0 | 4.0 | 6.3 | 12 | 35 | 16 | 5.90 |
| 9 | 1.0 | 4.0 | 4.5 | 9 | 28 | 14 | 4.10 |
| 10 | 1.0 | 6.0 | 5.5 | 11 | 29 | 23 | 6.20 |
| 11 | 1.0 | 4.5 | 5.7 | 10 | 28 | 8 | 3.40 |
| 12 | 1.0 | 5.0 | 5.5 | 9 | 33 | 9 | 4.00 |
| 13 | 1.0 | 5.0 | 6.7 | 11 | 34 | 6 | 2.60 |
| 14 | 1.0 | 4.0 | 5.7 | 10 | 31 | 10 | 1.50 |
| 15 | 1.0 | 4.0 | 6.6 | 10 | 31 | 3 | 1.25 |
| 16 | 1.1 | 3.0 | 5.8 | 9 | 22 | 6 | 4.75 |
| 17 | 1.5 | 3.0 | 7.4 | 10 | 27 | 2 | 5.00 |
| 18 | 1.2 | 2.5 | 5.7 | 9 | 29 | 2 | 1.50 |
| 19 | 1.1 | 4.0 | 6.8 | 10 | 30 | 5 | 4.15 |
| 20 | 1.1 | 4.5 | 6.2 | 11 | 29 | 10 | 5.75 |
| 21 | 1.2 | 3.0 | 6.5 | 9 | 32 | 6 | 2.00 |
| 22 | 1.0 | 3.5 | 7.5 | 10 | 29 | 10 | 1.00 |
| 23 | 1.0 | 6.3 | 6.3 | 11 | 34 | 11 | 3.25 |
| 24 | 1.4 | 3.0 | 6.6 | 10 | 15 | 9 | 4.10 |
| 25 | 1.0 | 5.0 | 6.3 | 9 | 27 | 10 | 3.35 |
| 26 | 1.2 | 4.5 | 8.4 | 9 | 35 | 12 | 5.00 |
| 27 | 1.0 | 4.0 | 8.7 | 11 | 31 | 7 | 2.75 |
| Av. | 1.08 | 4.0 | 6.4 | 9.9 | 30.3 | 9.0 | 3.62 |
| | | | *White Flour* | | | | |
| 1 | 1.2 | 6.0 | 7.7 | 10 | 37 | 9 | 4.35 |
| 2 | 1.1 | 3.0 | 5.3 | 9 | 26 | 12 | 1.50 |
| 3 | 1.3 | 5.0 | 7.6 | 9 | 29 | 9 | 2.50 |
| 4 | 1.1 | 5.0 | 5.9 | 10 | 22 | 12 | 3.50 |
| 5 | 1.8 | 6.0 | 5.7 | 10 | 25 | 6 | 1.75 |
| 6 | 1.0 | 6.0 | 5.5 | 11 | 31 | 9 | 0.75 |
| 7 | 1.0 | 4.5 | 7.6 | 10 | 29 | 6 | 5.50 |
| 8 | 1.3 | 6.0 | 5.9 | 9 | 16 | 23 | 2.25 |
| 9 | 1.0 | 5.5 | 6.0 | 10 | 33 | 7 | 4.50 |
| 10 | 1.0 | 5.0 | 6.6 | 11 | 33 | 12 | 3.15 |
| 11 | 1.2 | 4.5 | 5.4 | 10 | 31 | 8 | 2.15 |
| 12 | 1.0 | 6.0 | 7.1 | 10 | 31 | 18 | 4.00 |
| 13 | 1.2 | 7.0 | 7.9 | 10 | 40 | 9 | 8.75 |
| 14 | 1.0 | 3.5 | 7.7 | 10 | 27 | 11 | 2.00 |
| 15 | 1.0 | 4.5 | 6.1 | 8 | 18 | 16 | 2.25 |
| 16 | 1.0 | 3.5 | 8.3 | 11 | 33 | 14 | 4.15 |
| 17 | 1.1 | 4.0 | 7.3 | 10 | 23 | 10 | 1.50 |
| 18 | 1.1 | 5.0 | 7.2 | 11 | 40 | 10 | 0.90 |
| 19 | 0.9 | 4.0 | 7.8 | 11 | 31 | 3 | 4.60 |
| 20 | 1.0 | 5.5 | 6.4 | 12 | 34 | 8 | 3.50 |
| 21 | 1.1 | 4.0 | 7.0 | 10 | 25 | 6 | 5.75 |
| 22 | 1.4 | 4.0 | 6.6 | 10 | 30 | 8 | 5.70 |
| 23 | 1.0 | 4.5 | 7.5 | 10 | 36 | 6 | 4.50 |
| 24 | 1.0 | 5.0 | 7.8 | 11 | 31 | 8 | 2.40 |
| 25 | 1.0 | 5.0 | 6.6 | 11 | 27 | 14 | 3.25 |
| 26 | 1.0 | 4.0 | 5.3 | 10 | 24 | 12 | 3.50 |
| 27 | 1.0 | 6.0 | 9.5 | 11 | 34 | 8 | 3.50 |
| Av. | 1.10 | 4.9 | 6.9 | 10.2 | 29.5 | 10.2 | 3.41 |

TABLE 2—*Continued.*

| Specimen No. | Condensation | Width of culm (mm.) | Mean internode length (central spike) (mm.) | Glume length (mm.) | Length central spike (cm.) | No. sec. branches | Pedicel length (mm.) |
|---|---|---|---|---|---|---|---|
| | | | *Kokoma* | | | | |
| 1 | 1.2 | 4.0 | 6.7 | 9 | 14 | 8 | 3.75 |
| 2 | 1.0 | 5.5 | 6.2 | 10 | 20 | 8 | 4.10 |
| 3 | 1.2 | 6.5 | 5.7 | 9 | 28 | 15 | 2.90 |
| 4 | 1.0 | 5.0 | 5.7 | 9 | 25 | 12 | 2.25 |
| 5 | 1.0 | 5.0 | 6.3 | 9 | 26 | 9 | 3.50 |
| 6 | 1.2 | 5.0 | 5.3 | 9 | 26 | 4 | 1.60 |
| 7 | 1.3 | 3.0 | 4.9 | 9 | 22 | 5 | 4.00 |
| 8 | 1.4 | 5.0 | 6.0 | 9 | 23 | 4 | 1.40 |
| 9 | 1.1 | 5.0 | 5.7 | 8 | 24 | 11 | 3.25 |
| 10 | 1.0 | 5.0 | 5.0 | 8 | 22 | 12 | 3.00 |
| 11 | 0.9 | 4.0 | 5.2 | 9 | 23 | 4 | 4.25 |
| 12 | 1.4 | 4.5 | 5.4 | 7 | 25 | 8 | 3.50 |
| Av. | 1.1 | 4.8 | 5.7 | 8.8 | 23.2 | 8.3 | 3.13 |

GENETICS OF COLOR IN HOPI CORN.—*Blue Flour Corn.*—Blue Flour corn owes its color entirely to anthocyanin pigmentation in the aleurone layer of the endosperm. Genetically this may be represented as due to the dominant genes $A_1$ $A_2$ $C$ $R$ and $Pr$. The genes $A_1$ and $A_2$ are constant throughout all southwestern Indian maize so may be disregarded. The genes $C$ and $Pr$ appeared constant in this variety so far as observed. The $R$ series of alleles affect the anthocyanin coloration of the plant and pericarp as well as the aleurone. The characteristic allele for the Blue Flour may be designated as $R^g$ which gives fully-colored aleurone with no anthocyanin plant or pericarp color. In most of the stocks of Blue Flour there are admixtures of two other alleles $R^{nj}$ (Navajo pattern) giving white seeds tipped with blue ("Eagle-eye," "Flying Eagle" or "Navajo Sacred" corn) and $R^{st}$ (stippled) giving "stippled," "speckled" or "owl" corn. These alleles have long been associated with the Blue Flour and when planted separately give plants which are typical of the variety. The presence of white seeds due to contamination with recessive $r$ or $c$ is uncertain. The white kernels tested proved to be due to accidental crossing with White Flour corn.

*White Flour Corn.*—The aleurone is colorless due chiefly to the color inihibitor, an allele of the $C$ gene ($C^I$) or a very closely linked gene. Dominant $C$ (or rarely recessive $c$) may be present in populations which occasionally show ears with some colored kernels. The typical $R^g$ allele is similar to the one in the Blue Flour. The recessive $r^g$ allele is found very frequently; the stippled $R^{st}$ and Navajo patterns less frequently. Owing to the prevalence of the inhibitor, the kernels are mostly white, regardless of the $R$ constitution. Another variant is an $r^r$ allele which causes a little anthocyanin coloration in the plant and frequently a flush of purplish or rose color in the pericarp. These are often planted separately under the name of "Red" corn.

*Kokoma Corn.*—The dark purple color is due to purple anthocyanin coloration in the pericarp. This is due to a combination of the $r^{ch}$ or cherry allele of $R$ and the $Pl$ gene for plant color. This combination results in a plant with much purple pigment in the sheaths, husks and tassels especially in the later stages. This purple pigment is extended to the cob and pericarp. The only populations observed were segregating for both $Pl$ and $r^{ch}$, so dilute sun red and green plants occurred and many of the ears were white. The typically colorless aleurone is due primarily to the recessive $r$ factor. Small scale tests indicate that $C$ may be either dominant or recessive, with the dominant more frequent. The inhibitor was found only in plants where large size and higher row numbers indicated crossing with White Flour corn.

CYTOLOGY.—Numbers and position of chromosome knobs in the three Hopi varieties were obtained in 1951 from small cultures of plants grown in Iowa for this purpose. Plants of White and Blue Flour were grown from seed obtained at Hotevilla while the Kokoma plants were from seed collected at Walpi. The numbers of chromosome knobs obtained were 11 for Blue Flour, 13 for Kokoma and 12 for White Flour. Since these data are from one plant only of each variety, they give no indication of the range of variation within varieties. The number of chromosome knobs in the three varieties is quite high in comparison with other North American corns that have been studied (Longley, 1938; Brown, 1949); the numbers, however, are comparable to those of certain varieties from western Mexico.

Although there is little difference in total numbers of knobs in the samples taken, there are considerable differences in knob position (table 3). The samples from Blue and White Flour differed in five positions; White Flour and Kokoma in five; Blue Flour and Kokoma in ten. The significance of these

TABLE 3. *Number and position of chromosome knobs in Hopi maize.*

| Variety | Chromosomes | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | |
| Blue Flour | 0 | 1s | 2 | 1L[a] | 1 | 1 | 1L | 2 | 2 | 0 | 11 |
| Kokoma | 2 | 2 | 0 | 2 | 1 | 3 | 1L | 1 | 1t | 0 | 13 |
| White Flour | 1s | 2 | 1L | 1L | 1 | 2 | 1L | 2 | 1t | 0 | 12 |

[a]L–long arm; s–short arm; t–terminal.

differences is not clear since we know too little about the geographical distribution of specific chromosome knobs in maize.

DISCUSSION.—Carter and Anderson (1945) have presented evidence indicating that there have been at least three clearly defined waves of maize in southwestern United States. The first of these is that race associated with the prehistoric Basket Maker.[3] Superimposed upon Basket Maker maize there have been more recent introductions of at least two radically different types of corn, the addition of which complicate tremendously the variation pattern of historic varieties. One of these brings in a set of characters which are similar to those of Mexican dent corns and will hereafter be referred to as the "Mexican Influence." The other represents a type found in highland Guatemala and in the flint corns of eastern United States. Following the terminology of Carter and Anderson, it will be referred to as the Eastern complex. Certainly not all varieties of southwestern maize can be ascribed to some recombination of "Basket Maker," "Mexican" and "Eastern" entities, but it does seem apparent that these three races form the basic elements from which have arisen many of the multitudinous varieties and forms now present in the area. Fortunately, these races are so different from each other that one can make some progress in analyzing various mixtures between them.

Since our information on Basket Maker corn is limited to prehistoric material, we know very little about the vegetative parts of the plant. There are available, however, a vast number of cobs in various states of preservation as well as several reasonably good collections of unshelled ears. From these one can obtain a relatively accurate description of ear type. One of the best distinguishing features of Basket Maker ears is their shape. The widest diameter of the ear is at a subbasal position from which point there is a gentle taper toward the tip and a somewhat more abrupt taper toward the base. The base of the ear itself is usually strongly compressed and the basal kernels frequently exhibit distinct longitudinal husk markings. Row numbers most commonly found are 14 with a strong tendency toward spiral arrangement of the kernels. The kernels are about as thick as they are wide and are frequently hexagonal in cross-section. Shank attachments are relatively narrow suggesting an association with shanks of narrow diameter.

The Mexican influence introduces two characteristics of particular importance, (1) fasciation and (2) denting. The first results in an increased number of rows of kernels and a shortening of the internodes of the culm, shank and terminal inflorescences. With the exception of its final effect on the kernel, denting is little understood at the present. It is apparently due not only to the relative proportion, location and distribution of hard and soft starch in the endosperm, but also to inherent kernel shape which in turn may be modified by the degree of compression on the ear. Its ultimate expression varies all the way from a slightly perceptible depression at the top of the kernel to the other extreme in which the crown is completely collapsed. In inheritance the character is apparently controlled by the interaction of several genes and as a tool in classification is, therefore, of more value than were it a single factor difference. Although it is not known when or by what route or routes Mexican dents reached the American southwest, they apparently were in the area in pre-Columbian times and the existing evidence suggests (Carter and Anderson, 1945; Burgh and Scoggin, 1948) that they might have entered the southwest from the Northern Periphery rather than directly from Mexico. In any case, a survey of modern southwestern varieties leaves little doubt of the ultimate influence of Mexican dents on the evolution of that group of corns.

From the "Eastern" complex has come a number of easily distinguishable characteristics most of which have been described previously by Brown and Anderson (1947). These include (1) reduction in number of rows of kernels, (2) wide and short kernels, (3) increased length of ears, (4) lengthening of internodes in all plant parts, (5) tillering, and (6) the introduction of lax and narrow leaves. Another, and one of the more important distinguishing characteristics of Eastern complex material, is found in the shank and base of the ear. Shanks of this race, although long, are of unusually wide diameter. The increased diameter extends to the ear resulting, in many cases, in a greatly enlarged ear base. In its least extreme form the influence may still be detected by the presence of extra kernels and irregular rowing at the base of the ear. These morphological features, it will be noted, are directly opposite those characterizing Mexican dents and are also in many ways different from Basket Maker corn.

It was at one time felt that the flint corns of eastern United States spread into that area from the southwest, but more recent archaeological evidence leaves little doubt that Eastern complex characteristics present in southwestern corns have resulted from the movement of Eastern corns into the Southwest and at a relatively late date (probably after

[3] Basket Maker maize should not be confused with the earlier Bat Cave material described by Manglesdorf and Smith which dates back to about 2000 B.C.

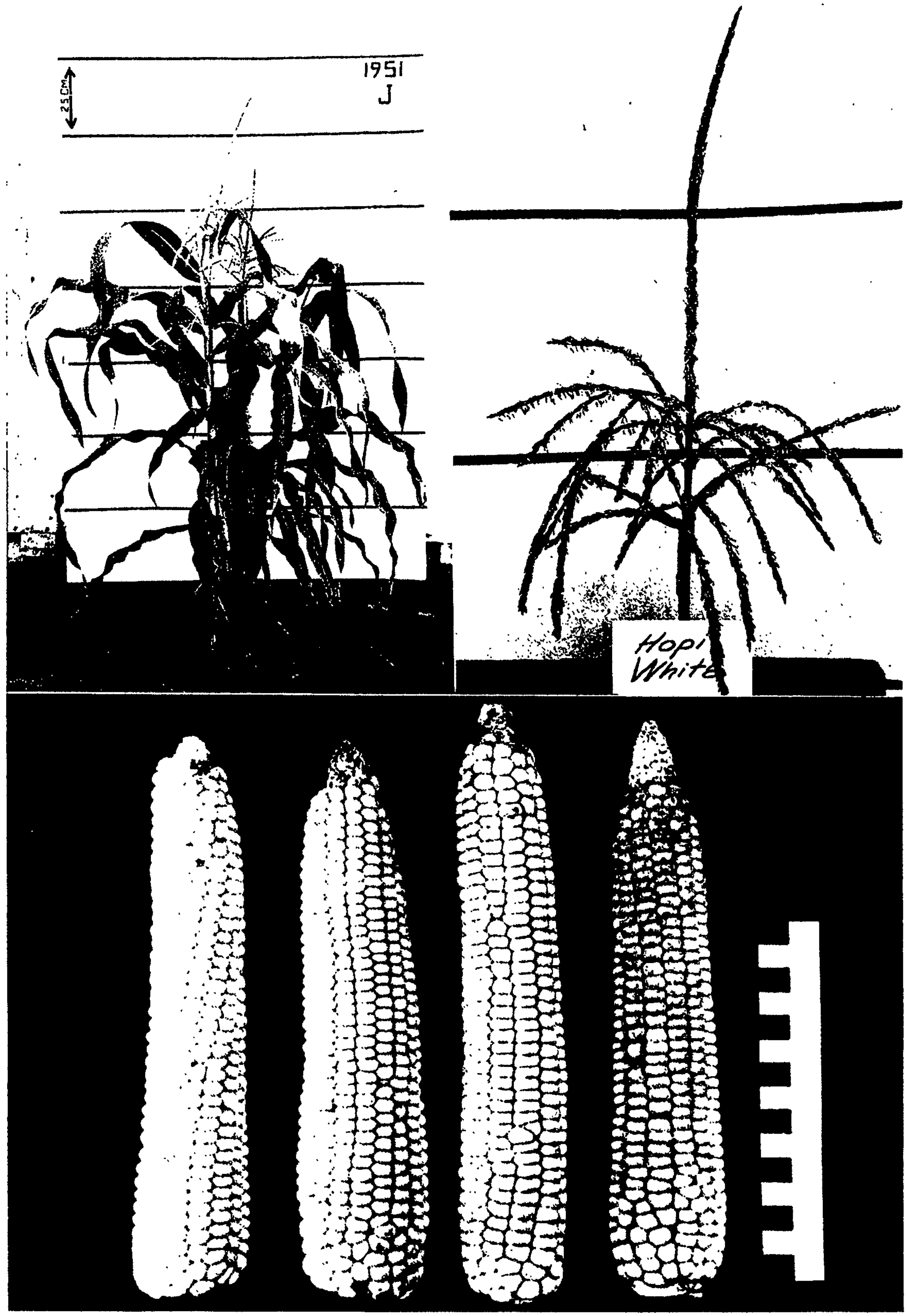


Fig. 5. See page 608 for legend.

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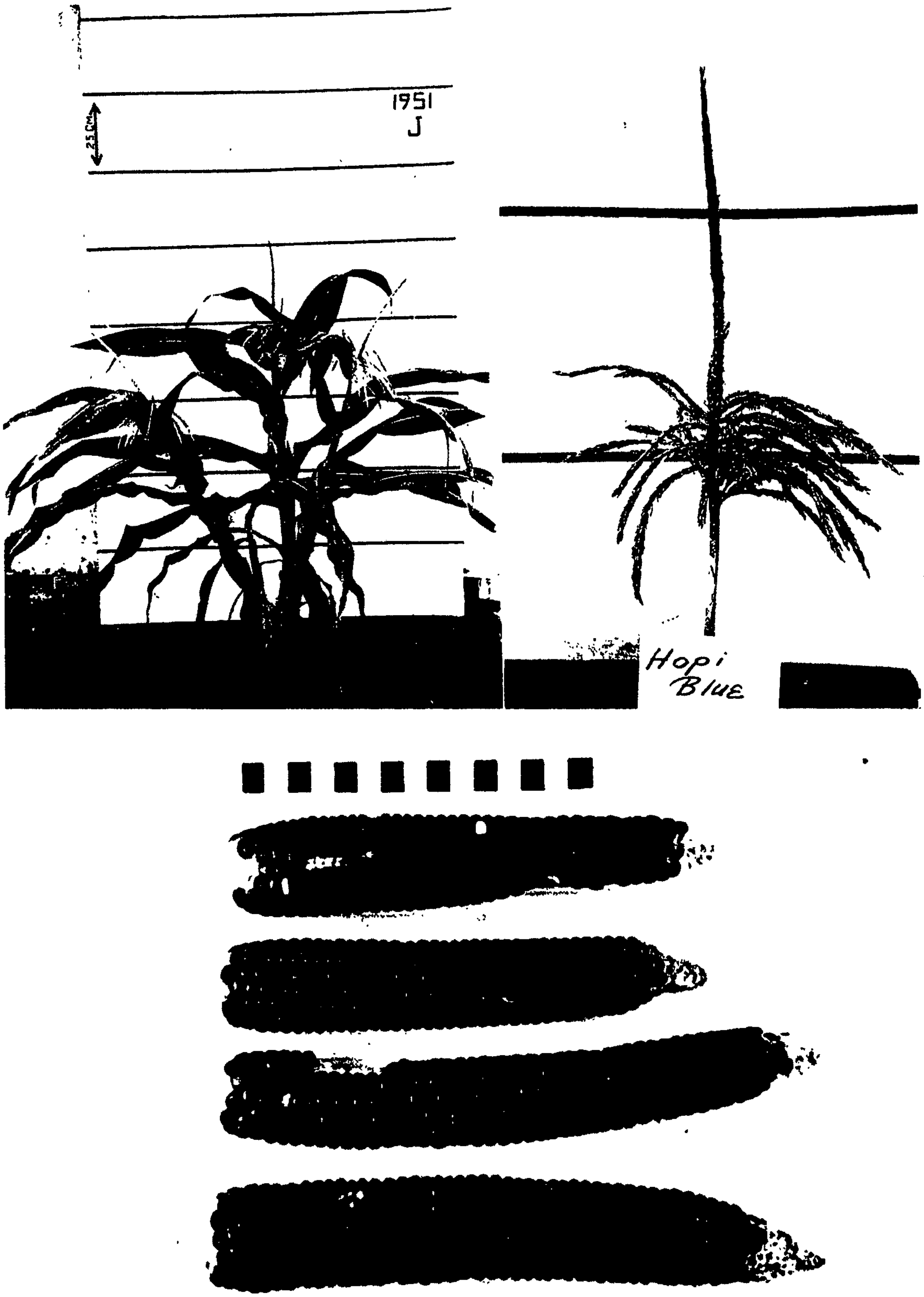


Fig. 6. See page 608 for legend.

HP269

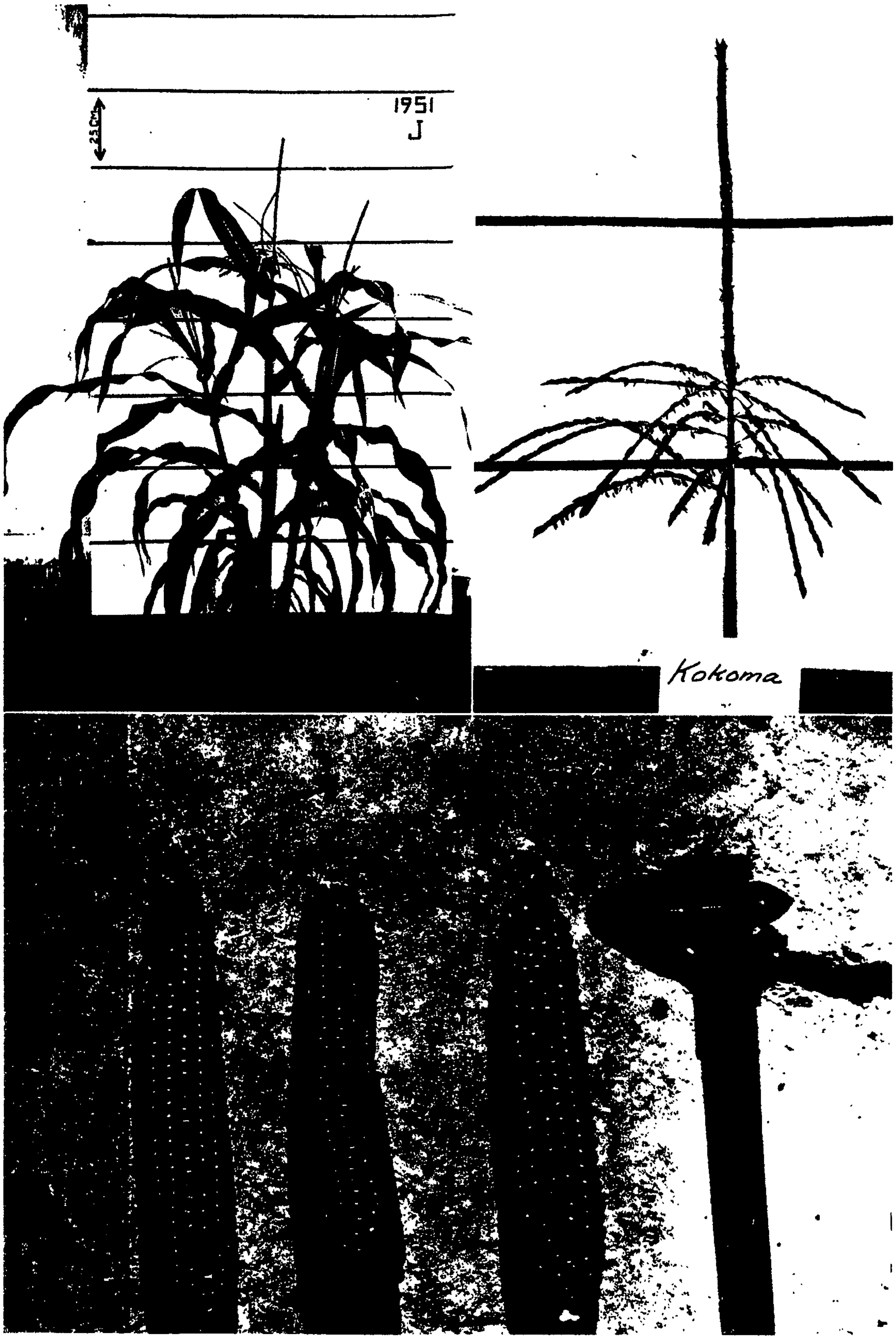


Fig. 7. See page 608 for legend.

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1200 A.D.). The bringing together of Eastern sorts with varieties already present in the Southwest have probably, as a result of repeated hybridization, produced the long-eared strains of the modern pueblos.

Using the characteristics of the three major races as a background, it is interesting to compare the influence of each on the three Hopi varieties with which we are dealing. The results of a preliminary attempt to summarize such an analysis are presented pictorially in the form of a scatter diagram in fig. 4. In the diagram, mean internode length of the central spike, on the horizontal axis, is plotted against width of culm at the base of the tassel, on the vertical axis. Since these characters tend to separate Eastern and Mexican influence from that of Basket Maker, and since they are also associated with other distinguishing features of Eastern and Mexican corns, any tendency toward separation of the varieties on the diagram is probably of significance. Each symbol represents the position of an individual plant score and varieties are distinguished by the use of different symbols. Although there is no clear-cut separation of varieties, the distribution shows a stronger tendency in the direction of both Eastern and Mexican influence for White Flour than it does for Blue. Kokoma corn, on the basis of these measurements, shows only slight evidence of admixture with Eastern germ plasm. The frequency distributions of the various classes (fig. 4) present in another form the same relationships depicted in the scatter diagrams. Furthermore, additional evidence for a strong Eastern influence in White Flour is shown in the distribution of shank measurements in fig. 3. Although there is considerable overlapping of shank diameters among the three varieties, a sizeable segment of White Flour individuals is completely outside the range of variation of the other two varieties. Since this segment is in the direction of Eastern complex and since wide shanks could hardly have reached the Southwest from another source, it seems reasonable to suppose that White Flour is more closely related to Eastern complex corns than are the other varieties. A further example of the same general tendency is provided by the data on row number and kernel width. It will be remembered that few rows and wide kernels are typical of the Eastern complex corns. While White and Blue Flour cannot be separated on the basis of row numbers, they are readily separable by kernel width as is shown in fig. 2. Here it will be noted that kernel widths of White Flour are almost completely outside the range of Blue and in the direction of Eastern complex. The results obtained from an analysis of several individual morphological characteristics (internode lengths of central spike, shank diameter, kernel width) all point in the same direction, suggesting that White Flour is more closely allied to Eastern complex corns than are either of the other varieties considered. Furthermore, because of its close similarity to prehistoric Basket Maker maize, the variety Kokoma probably represents the most primitive of the three races, while Blue Flour assumes a position more or less intermediate between White Flour and Kokoma.

## SUMMARY

From collections obtained from the more conservative Hopi Indian villages the variation patterns of several morphological characters were determined for three major varieties of modern Hopi maize. The three varieties, White Flour, Blue Flour and Kokoma, are examined and compared in light of what is known of the evolutionary history of southwestern maize in general. Although the three varieties have much in common, White Flour exhibits to a greater degree the effects of introgression of both Mexican and Eastern germ plasm than do either of the other two varieties. Kokoma corn, on the basis of comparative morphology, appears to be closer to prehistoric Basket Maker maize than either of the other varieties, while Blue Flour is in many ways intermediate between Kokoma and White Flour. The genetics of color factors in Hopi maize is discussed. The characteristic alleles of each of the three varying factors for anthocyanin coloration are, Blue Flour: $C\ R^{g}\ pl$; White Flour: $C^{I}\ R^{g}\ pl$; Kokoma: $C\ r^{ch}\ Pl$. Numbers and positions of chromosome knobs were determined from single plants of each of the three strains. Although total knob numbers are similar in each of the varieties, there are marked differences in knob positions.

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Fig. 5. Representative plant, tassel and ears of Hopi White Flour. Each division on the background of plant and tassel photographs represents 25 cm. Each division on the scale opposite the ears equals 1 cm. Plants and tassels are from specimens grown in Iowa. Ears are from Arizona grown plants.

Fig. 6. Representative plant, tassel and ears of Hopi Blue Flour. Each division on the background of plant and tassel photographs represents 25 cm. Each division on the scale opposite the ears equals 1 cm. Plants and tassels are from specimens grown in Iowa. Ears are from Arizona grown plants.

Fig. 7. Representative plant, tassel and ears of Hopi Kokoma maize. Each division on the background of plant and tassel photographs represents 25 cm. Plants and tassels are from specimens grown in Iowa. Ears are from Arizona grown plants.

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